Chapter 1
Introduction

The US Environmental Protection Agency's (EPA) Underground Injection Control (UIC) Program is conducting a study to evaluate impacts to underground sources of drinking water (USDWs) from hydraulic fracturing practices used in coalbed methane production.

The EPA, under Section 1421(b)(1) of the Safe Drinking Water Act (SDWA), is tasked to protect USDWs, which are the source of ground water for all current and future drinking water supplies across the country. A complete USDW definition is provided in Section 1.3. EPA's UIC Program is responsible for ensuring that fluids injected into the ground (for reasons including: disposal, mining, and enhanced recovery of oil and natural gas) do not adversely affect public health or cause a public water system to violate its drinking water standards due to the contamination of a USDW by these injected fluids.

The goal of this first phase of the hydraulic fracturing study was to determine if a threat to public health as a result of USDW contamination from hydraulic fracturing of coalbed methane (CBM) wells exists, and if that threat is great enough to warrant further study. EPA reviewed the potential of hydraulic fracturing to impact USDWs through one of two mechanisms: 1) direct injection of fracturing fluids into a USDW in which the coal is located, or 2) creation of a hydraulic connection between the coalbed formation and an adjacent USDW. The study consists of a literature review of the geologic settings and the hydraulic fracturing practices utilized in eleven major coalbed basins (Figure 1-1); a review of ground water contamination incidents in coalbed methane production areas; and solicitation of information from the public on any impacts to ground water believed to be associated with hydraulic fracturing.

1.1 Why Did EPA Decide to Conduct This Study?

Although the use of coalbed methane as an energy source has many environmental benefits over traditional energy sources, concerns have been raised regarding the environmental impacts of coalbed methane production. Coalbed methane production in certain areas has led to ground water depletion and production water discharge issues. Citizens, state agencies, producers, and the regional EPA offices in those areas are working in concert to understand and mitigate potential problems. Separate from ground water depletion and water discharge issues are allegations that hydraulic fracturing of coalbed methane wells has impacted the quality of ground water. State oil and gas agencies receiving such complaints have stated that, based on their investigations, hydraulic fracturing has not contributed to water quality degradation.

The State of Alabama recently adopted hydraulic fracturing regulations into its UIC program in response to an 11th Circuit Court of Appeals (hereafter, "the Court") decision (LEAF v. EPA, 118F.3d 1467). Prior to the Court's decision, EPA had not considered hydraulic fracturing as underground injection because it did not regard production well stimulation as an activity subject to regulation under the UIC program. However, the Court held that the injection of fluids for the purpose of hydraulic fracturing constitutes underground injection as defined under the SDWA, that all underground injection must be regulated, and that hydraulic fracturing of coalbed methane wells in Alabama was not regulated under Alabama's UIC program.

Based on a high level of interest of stakeholders, EPA decided that further investigation was necessary to evaluate any potential threats before the Agency can make any further regulatory or policy decisions regarding hydraulic fracturing. This first phase of a fact-finding study was designed to assist EPA in that determination.

1.2 What is Hydraulic Fracturing?

Hydraulic fracturing is a technique used by the oil and gas industry to improve the production efficiency of oil and coalbed methane wells. A hydraulically created fracture acts as a conduit in the rock or coal formation that allows the oil or coalbed methane to travel more freely from the rock pores, where it is trapped, to the production well that can bring it to the surface.

In the case of coalbed methane gas production, the gas is trapped in tiny, disconnected clusters of fractures (called "cleats") within a coal layer. The coal layer is typically sandwiched between layers of dense rock, such as shale, sandstone or limestone, which prevents the coalbed methane from migrating up and away from the coal. To extract the coalbed methane, a production well is drilled through the rock layers to intersect the coal seam containing the coalbed methane. Next, a fracture must be created in the coal seam to intersect the tiny, gas-bearing fractures and create a pipeline through which the coalbed methane can travel to the well so it can be brought to the surface.

To create such a fracture, a thick, water-based fluid is pumped into the coal seam at a gradually increasing rate. At a certain point, the coal seam will not be able to accommodate the fracturing fluid as quickly as it is being injected. When this occurs, the pressure is high enough that the coal gives way and a fracture is created. To hold the fracture open, a propping agent, usually sand (commonly known as "proppant"), is pumped into the fracture so that when the pumping pressure holding the fracture open is released, the fracture does not close completely because the proppant is "propping" it open. The resulting fracture filled with proppant is a conduit through which coalbed methane trapped in the formation can flow to the well.

The extent of the fracture is controlled by the characteristics of the geologic formation, the fracturing fluid used, the pumping pressure, and the depth at which the fracturing is being performed. The fracture always initiates from the well and extends out as two separate wings in opposite directions. Whether the fracture grows higher or longer is determined by the surrounding rock properties. A hydraulically created fracture will always take the path of least resistance through the coal seam and surrounding formations.

A more comprehensive discussion of the fracturing process and the fracturing fluids and additives used in hydraulic fracturing of coalbed methane wells is presented in Chapters 3 and 4.

1.3 How Does EPA Protect Underground Sources of Drinking Water?

Congress recognized the resource nature of ground water, and intended that EPA protect not only current drinking water sources, but also aquifers that had the potential to serve as drinking water sources in the future. EPA's UIC Program is authorized by the SDWA to protect public health from threats arising from contamination of USDWs resulting from underground injection activities. However, SDWA does not authorize EPA to regulate oil and gas production practices. A USDW is defined in the regulations governing Underground Injection Control programs under the Safe Drinking Water Act (40 CFR 144.3), as follows:

An *Underground Source of Drinking Water (USDW)* is defined as an aquifer or its portion that:

A.
  1. supplies any public water system; or
  2. contains sufficient quantity of ground water to supply a public water system; and
    i. currently supplies drinking water for human consumption; or
    ii contains fewer than 10,000 milligrams per liter (mg/L) total dissolved solids (TDS);

and

B. is not an exempted aquifer.

The water quality criteria for USDWs is more inclusive than EPA's National Secondary Drinking Water Standards for potable water which cover aesthetic concerns such as taste and odor. These secondary standards recommend a TDS limit at 500 mg/L (40 CFR 143.3).

An accurate understanding of the definition of USDW requires interpretation of two other terms: *public water system* and *aquifer exemption*.

Public water system is defined in 40 CFR ' 141.2 in part as:

> "A system for the provision to the public of water for human consumption through pipes or, after August 5, 1998, other constructed conveyances, if such a system has at least 15 service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year."

According to EPA interpretation (USEPA Memorandum, 1993), any aquifer that yields more than 1 gallon per minute can be expected to provide sufficient quantity of water to serve a public water system and therefore falls under the definition of a USDW. EPA assumes that all aquifers contain sufficient quantity of ground water to supply a public water system, until proven otherwise through empirical data.

Aquifer exemptions are granted for aquifers that contain commercial minerals (such as oil, gas, uranium and table salt) or for the purpose of injection (www.epa.gov/safewater/uic/usdw.html). According to 40 CFR 144.3, an exempted aquifer meets the definition of underground source of drinking water but has been exempted according to the procedures in 40 CFR 144.7. An aquifer or portion thereof can be designated as an exempted aquifer, if it meets the following criteria (40 CFR 146.4):

1) It does not currently serve as a source of drinking water; and,
2) It cannot now and will not in the future serve as a source of drinking water because:
   - It is mineral, hydrocarbon or geothermal energy producing, or can be demonstrated to be commercially producible, or
   - It is situated at a depth or location which makes recovery of water for drinking water purposes economically or technologically impractical, or
   - It is so contaminated that it would be economically or technologically impractical to render that water fit for human consumption, or
   - It is located over a Class III well mining area subject to subsidence or catastrophic collapse; or,
3) The total dissolved solids content of the ground water is more than 3,000 and less than 10,000 mg/L, and, it is not reasonably expected to supply a public water system.

All requests for aquifer exemption must be approved by the Administrator or an authorized representative, as part of a UIC-program. A list of exempted aquifers, for states where such exemptions exist, is maintained by the State agency managing the UIC program or the regional USEPA office.

A comprehensive list or map identifying all USDWs in each state does not exist; identification of USDWs is an ongoing effort, as is EPA's consideration of aquifer exemptions. Coalbed methane production wells using hydraulic fracturing to stimulate production may be located in areas that coincide with existing aquifer exemptions.

Currently, injection associated with hydraulic fracturing of coalbed methane production wells is regulated only in the State of Alabama under the state UIC program, and that injection activity falls under the category of Class II wells (State Oil and Gas Board of

Alabama, Administrative Code, Oil and Gas Report 1, 400-3). Class II wells include the injection of brines and other fluids that are associated with oil and gas production.

1.4 How Could Hydraulic Fracturing of Coalbed Methane Wells Potentially Impact A USDW?

The first step in investigating the potential for hydraulic fracturing to threaten USDWs was to define mechanisms by which a threat could occur. Based on its authority under the UIC Program, EPA identified two possible mechanisms by which hydraulic fracturing of coalbed methane wells could potentially impact USDWs:

1. The injection of fracturing fluids into a USDW; and,
2. Creation of a hydraulic connection between the target coalbed formation and adjacent USDWs.

The objectives of the Phase I study were to evaluate these two mechanisms and determine, based on existing literature and data, if USDWs are threatened.

The injection of fracturing fluids into a USDW can happen directly or indirectly depending on the location of the coalbed relative to a USDW. In many coalbed methane-producing regions, the target coalbeds occur *within* USDWs, and the fracturing process injects stimulation fluids directly into the USDWs (Figure 1-2). In other production regions, target coalbeds are adjacent to the USDWs that exist either higher or lower in the geologic section. Hydraulic fracturing in coalbed methane formations may create fractures that are taller than they are long (Morales et al, 1990; Zuber, 1990; Holditch et al, 1989; Palmer et al, 1991, 1991a, 1993). EPA investigated the potential for fractures to extend through the stratigraphic layers that separate coalbeds and USDWs and for stimulation fluids to indirectly enter a USDW during the fracturing process (Figure 1-3).

Once the fracturing fluids are injected into a formation, local geologic conditions may interfere with their complete recovery. This may result in fracturing fluids being “stranded” in a USDW (Figures 1-2 and 1-3). If hazardous materials are included in the stimulation fluids, they could potentially contaminate ground water within a USDW and any drinking water supplies relying on the USDW.

1.5 How Is EPA Conducting Its Study?

Given the enormous variation in geology among and within coalbed basins in the United States, any initial evaluation of potential impacts at a national level will necessarily be broad and general in scope. In order to best utilize resources in investigating this issue, EPA has divided the study into three phases, narrowing its focus from general to more specific as needed. At the completion of each phase, EPA will decide if findings warrant continuation into the next phase.

Phase I of the study is a limited-scope assessment designed to enable the Agency to determine if a threat to public health as a result of USDW contamination from CBM hydraulic fracturing exists and if so, if that threat is great enough to warrant further study. An overview of the methodology used for Phase I is provided below; a detailed discussion of this methodology is provided in Chapter 2.

In Phase I, EPA has:

- Gathered existing information to review hydraulic fracturing processes, practices, and settings;
- Requested public comment to identify incidents that have not been reported to EPA; and,
- Reviewed reported incidents of ground water contamination and any follow-up actions or investigations by other parties such as the State or local agencies, industry, and academia.

In addition, EPA has collaborated with the Department of Energy (DOE) to produce a document that details the technical aspects of hydraulic fracturing in the oil and gas industry. This document has been included as Appendix A of this report.

EPA has also provided support for a site-specific study, which will be conducted by the Geological Survey of Alabama (GSA). This study will attempt to address a concern that is central to contamination and drawdown issues - the degree to which flow is confined within coal beds in coalbed methane fields (GSA, June, 2000). Additional information is available on the GSA's web site at
http://www.gsa.state.al.us/gsa/3DFracpage/3Dfracstudy.htm.

1.6 How Has EPA Involved Stakeholders?

EPA has been taking several steps to fully involve the public and all stakeholders during the course of the study. These steps include publishing *Federal Register* notices requesting comments on study plans and draft work products; requesting information from the public on any impacts to ground water believed to be associated with hydraulic fracturing; providing periodic updates for stakeholders in the form of written communication; and maintaining a web site where stakeholders can view the project documents and provide information to EPA.

1.7 What Information Will I Find in This Report?

The Phase I findings are presented in a report comprised of seven chapters, eleven attachments, and two appendices. The main chapters deal with the following topics:

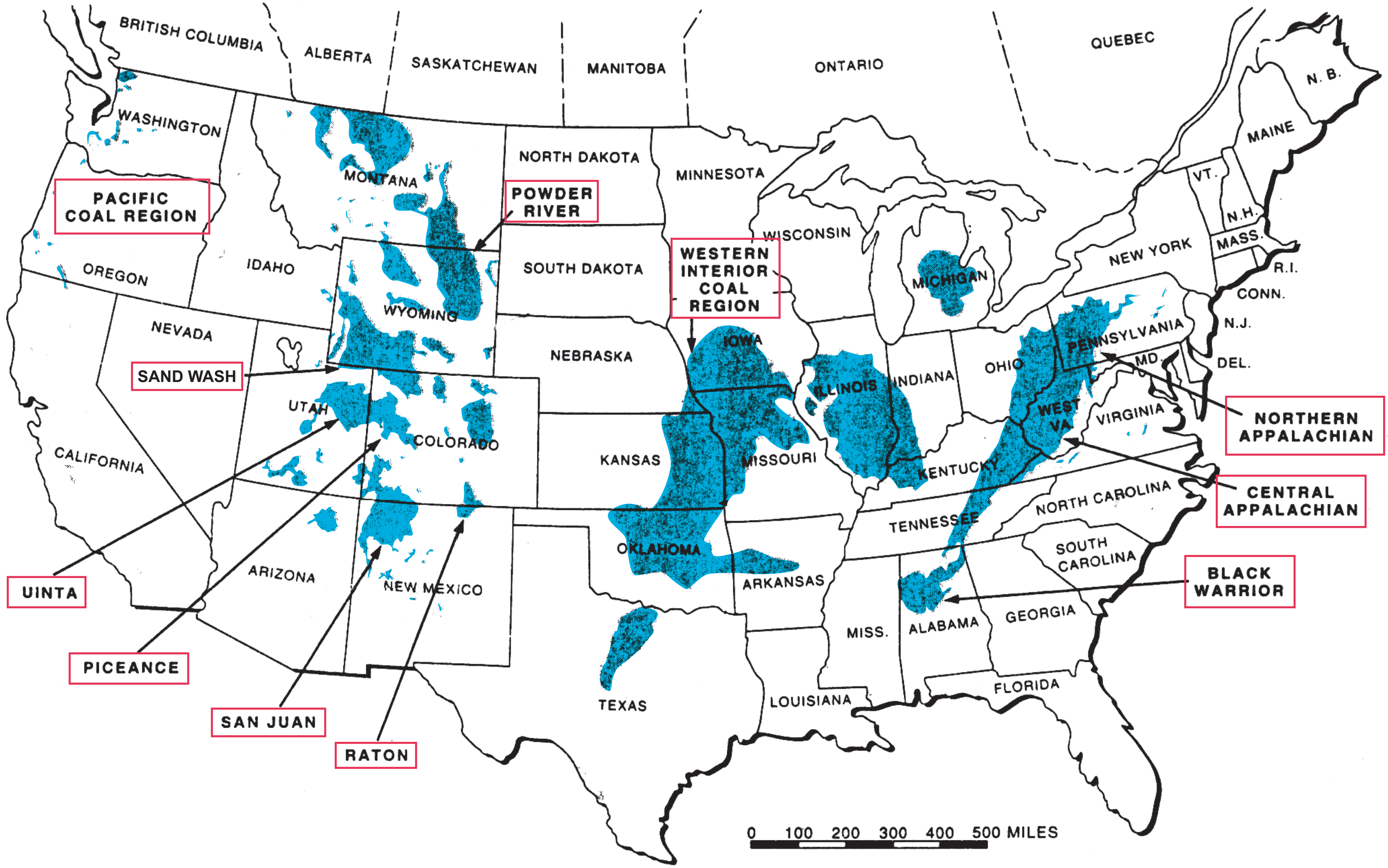
- Chapter 2, Study Methodology: provides a detailed discussion of EPA's method for collecting information under Phase I of the study.

- Chapter 3, Characteristics of Coalbed Methane Production and Associated Hydraulic Fracturing Practices: provides a discussion of the hydraulic fracturing process as it applies to coalbed methane production.
- Chapter 4, Hydraulic Fracturing Fluids: presents a description of the use and nature of hydraulic fracturing fluids and their additives, and discusses the possibility that injection of these fluids could impact the water quality of USDWs.
- Chapter 5, Summary Of Coalbed Methane Basin Descriptions: provides a brief description of each of the 11 major coal basins in the United States and a discussion of the potential for impacts to USDWs located within these basins.
- Chapter 6, Water Quality Incidents: provides a summary of water quality complaints pertaining to hydraulic fracturing and coalbed methane production and well stimulation.
- Chapter 7, Summary of Findings: provides a summary of the major findings presented in Chapters 3 through 6.

The main report's chapters also contains numerous figures and tables that assist the reader in visualizing the hydraulic fracturing process and help to summarize some of the key information presented in the report.

The attachments section of the report is a collection of in-depth hydrologic investigations of each of the coal basins, focusing primarily on the coalbed methane production activities in each basin and the relationship of coalbed and USDW locations with respect to each other in each of the basins. The attachments are meant to complement the main report by presenting the basin-specific information acquired to describe basin activities and unveil the differences in geology and production activity across the country.

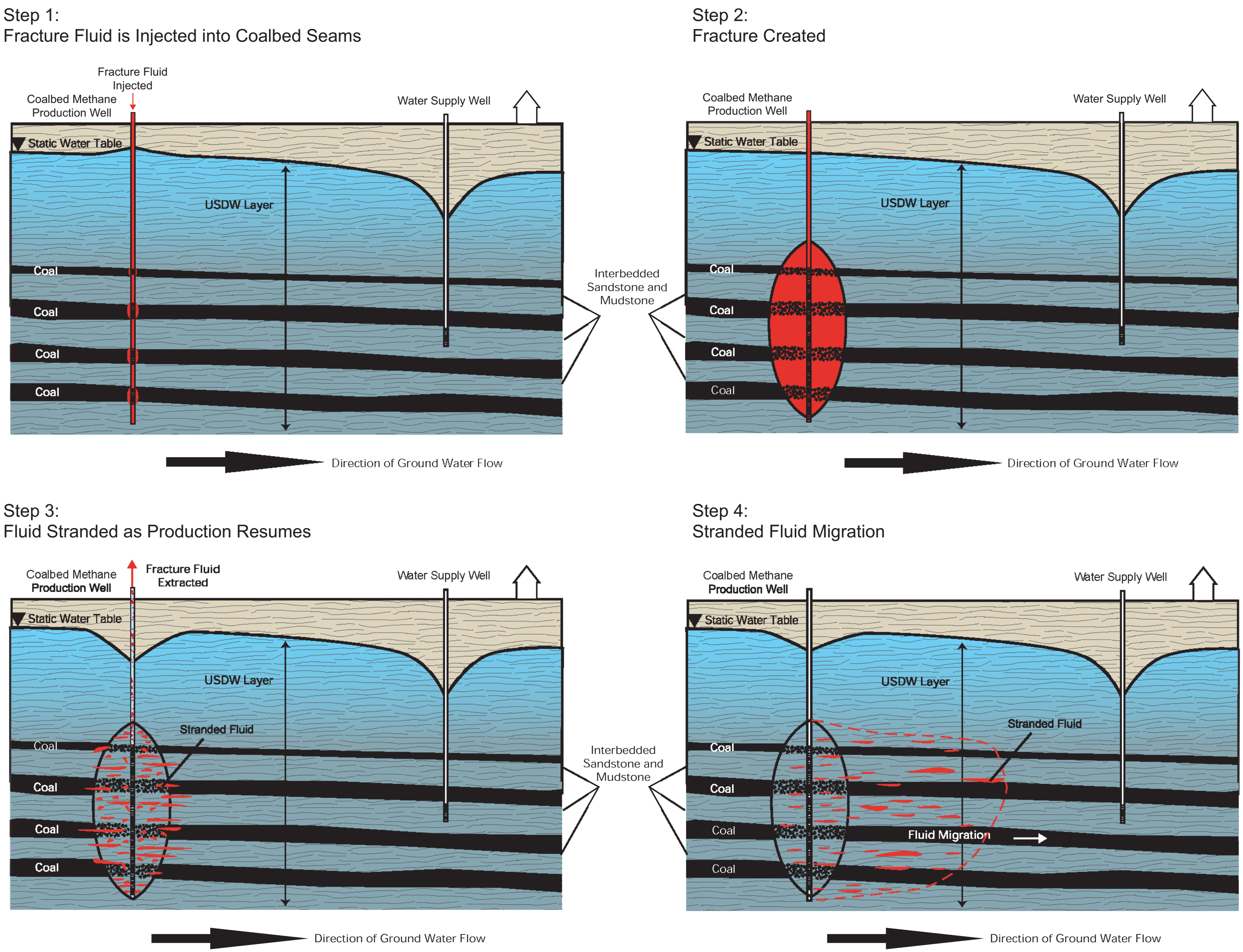
Appendix A, Hydraulic Fracturing, contains DOE's technical report on hydraulic fracturing. Appendix B, Quality Assurance Protocol, explains the quality assurance and quality control measures EPA used for this study.



Locus Map of Major U.S. Coal Basins
(Quarterly Review, Methane From Coal Seams Technology, 1993)

1027/reports/ch1/fig-1-1.eps

Figure 1-1



Mechanism #1 - Direct Fluid Injection Into A USDW (Coal Within USDW)

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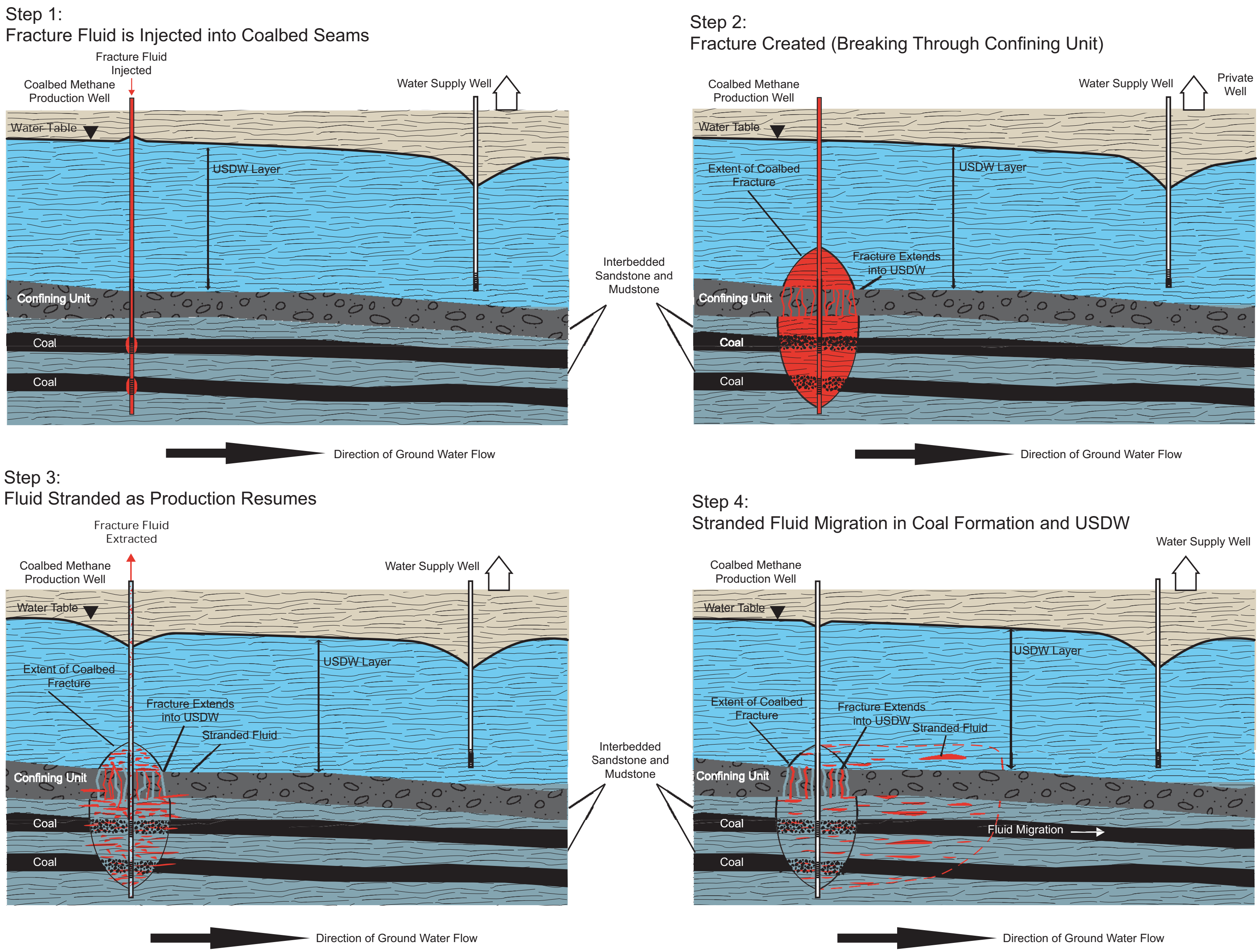

Mechanism #2 - Fracture Creates Connection to USDW

1027/reports/ch1/1027-fig-1-3.eps	Figure 1-3